AMENDMENTS TO THE SPECIFICATION

Page 1, please delete line 4 and substitute therefor the following:

~~TECHNICAL~~ FIELD OF THE INVENTION

Page 1, please delete line 7 and substitute therefor the following:

~~BACKGROUND~~ DESCRIPTION OF THE RELATED ART

Page 1, please delete the paragraph beginning at line 8 and substitute therefor the following:

In the past, electron irradiation has been utilized to surface modify, sterilize or clean an object. For example, Japanese Patent Early Publication [kokai] No. 2002-6094 discloses an electron irradiating apparatus that can be used to form a cross-bridge structure or purify exhaust gas. This apparatus is provided with an electron gun having a hot filament, a high-voltage power source for supplying an electric current to the hot filament to generate electrons, an accelerating electrode for accelerating the generated electrons to obtain an electron beam, and an electromagnet for deflecting the electron beam.

Page 1, please delete the paragraph beginning at line 16 and substitute therefor the following:

However, ~~since~~ because the hot filament is an electron source having a spot-like or linear electron emitting portion, it is ~~needed~~ necessary to scan the electron beam to modify a relatively wide surface area of the object. This leads to a reduction in treatment efficiency, and a complication in device structure. In addition, ~~since~~ because the hot filament is heated under a high degree of vacuum to generate the electrons, vacuum ~~equipments~~ equipment such as a decompression chamber and a vacuum pump are needed. As a result, there is a problem that the application area of the apparatus is narrow despite an increase in cost of the apparatus.

Page 2, please delete line 3 and substitute therefor the following:

~~SUNNARY~~ SUMMARY OF THE INVENTION

Page 2, please delete the paragraph beginning at line 8 and substitute therefor the following:

That is, the method of the present invention comprises the steps of providing a cold-cathode electron emitter, which has the capability of emitting electrons from a planar electron emitting portion according to tunnel effect, applying a voltage to the emitter to emit the electrons from the planar electron emitting portion, and exposing the object to the emitted electrons. As the cold-cathode electron emitter, it is particularly ~~preferred~~ preferable to use a Ballistic electron Surface-emitting Device (BSD) comprising a pair of electrodes, and a strong field drift layer including nanocrystalline silicon disposed between the electrodes.

Page 2, please delete the paragraph beginning at line 17 and substitute therefor the following:

According to the present invention, ~~since~~ because the cold cathode electron emitter that is a planar-type electron emitting source is used, it is possible to perform the modifying treatment to the object under a reduced pressure near atmospheric pressure in addition to the improvement in treatment efficiency and uniformity. In particular, when using the BSD as the cold cathode electron emitter, it is possible to perform the modifying treatment under [[the]] atmospheric pressure without using vacuum equipments such as a vacuum pump and decompression chamber. Therefore, there are many advantages of an expansion of the application area, downsizing of the apparatus, and a reduction in cost of the modifying treatment.

Page 3, please delete the paragraph beginning at line 5 and substitute therefor the following:

In the above method, it is ~~preferred~~ preferable that an energy of the electrons used to modify the object is selected from a range of 1 eV to 50 keV, and preferably 1 ~ 100 eV.

Page 3, please delete the paragraph beginning at line 8 and substitute therefor the following:

A further concern of the present invention is to provide an apparatus for efficiently and uniformly modifying an object with electrons. That is, this apparatus comprises a cold-cathode electron emitter, which has the capability of emitting electrons from a planar electron emitting portion according to tunnel effect, voltage applying unit for applying a voltage to the emitter to emit the electrons from the planar electron emitting portion, and a case for accommodating the emitter therein. The case has an opening, through which the electrons or a gas activated by the electrons are provided. From the same reason as the above, it is particularly ~~preferred~~ preferable to use a Ballistic electron Surface-emitting Device (BSD) as the cold-cathode electron emitter, which comprises a pair of first and second electrodes, and a strong field drift layer including nanocrystalline silicon disposed between the first and second electrodes.

Page 3, please delete the paragraph beginning at line 21 and substitute therefor the following:

In addition, it is ~~preferred~~ preferable that the above apparatus further comprises an accelerating electrode positioned in face-to-face relation with the planar electron emitting portion to accelerate the electrons. In this case, it is possible to control the energy of electrons irradiated to the object.

Page 3, please delete the paragraph beginning at line 25 and substitute therefor the following:

In the above apparatus, it is ~~preferred~~ preferable that the first electrode is composed of an array of first electrode strips, which are arranged to be spaced from

each other in a lateral direction, and the second electrode is composed of an array of second electrode strips, which are arranged to be spaced from each other in a direction intersecting with the lateral direction, wherein the electrons are selectively emitted from the planar electron emitting portion corresponding to an intersecting region(s) between at least one of the first electrode strips and at least one of the second electrode strips when the voltage is applied therebetween by the voltage applying unit. Furthermore, it is ~~preferred~~ preferable that the apparatus has [[an]] a first selector for selecting at least one of the first electrode strips, and a second selector for selecting at least one of the second electrode strips, wherein the voltage applying unit applies the voltage between at least one of the first electrode strips selected by the first selector and at least one of the second electrode strips selected by the second selector to selectively emit the electrons from the planar electron emitting portion corresponding to the intersecting region(s) therebetween. In this case, it is possible to change a modification area depending on the size of the object, thereby achieving energy saving and reducing the modification cost.

Page 6, please delete line 9 and substitute therefor the following:

~~BEST MODE FOR CARRYING OUT THE INVENTION~~ DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Page 6, please delete the paragraph beginning at line 13 and substitute therefor the following:

As shown in FIGS. 1 and 2, an apparatus for modifying an object **2** with electrons according to the present embodiment comprises a cold cathode electron emitter **1** having a planar electron emitting portion **10**, a voltage applying unit **30** for applying a voltage to the emitter to emit electrons from the planar electron emitting portion, a case **20** for accommodating the emitter therein, which is made of an insulating material and has an opening **21** used to ~~provide~~ permit the emitted electrons to travel to the outside of the case, and a holder **40** for supporting the object **2** such that the object is exposed to the electrons provided through the opening. In FIG. 1, the numeral **50** designates a mesh electrode attached to the opening **21** to accelerate the

electrons generated from the emitter **1**. Alternatively, a window member made of a material, through which the electrons can pass, may be attached to the opening in place of the accelerating electrode.

Page 6, please delete the paragraph beginning at line 26 and substitute therefor the following:

As shown in FIG. 2, the cold cathode electron emitter **1** comprises a conductive substrate **14** such as n-type silicon, a non-doped polycrystalline silicon layer **13** formed on a top surface of the conductive substrate **14**, strong-field drift layer **12** formed on the polycrystalline silicon layer **13**, a first electrode **11** provided on the strong-field drift layer **12**, and an ohmic electrode **15** formed on the bottom surface of the conductive substrate **14**. In this case, the conductive substrate **14** and the ohmic electrode **15** function as a second electrode. In addition, a top surface of the first electrode **11** provides the planar electron emitting portion **10** of the emitter **1**. The strong-field drift layer **12** may be directly formed on the conductive substrate not through the polycrystalline silicon layer **13**. Alternatively, another cold cathode electron emitter **1** shown in FIG. 3 may be used, ~~which is characterized~~ in ~~that~~ which an insulating substrate **16** such as glass or a ceramic material is used in place of the conductive substrate **14**, an electrode layer **17** is formed as the second electrode on the insulating substrate, and the strong-field drift layer **12** is formed on the electrode layer **17**. The cold cathode electron emitter **1** used in this embodiment is known as "Ballistic electron Surface-emitting Device" (BSD).

Page 9, please delete the paragraph beginning at line 2 and substitute therefor the following:

To emit electrons from the cold cathode electron emitter **1**, when a required voltage is applied between the first electrode **11** and the ohmic electrode **15** such that an electric potential of the first electrode is higher than the electric potential of the ohmic electrode, electrons are injected from the second electrode into the strong field drift layer **12**. At this time, ~~since~~ because most of the electric field is impressed to the first and second silicon oxide thin films (**110**, **130**) of the strong field drift layer **12**, the

injected electrons are accelerated by the strong electric field impressed to those silicon oxide thin films, so that the electrons are drifted in regions between the silicon grains **100** of the strong field drift layer **12**, as shown by the arrows in FIG. 4, and emitted outside through the first electrode **11** without being almost scattered by the fine grains of nanocrystalline silicon **120**. This phenomenon is called [[as]] a "Ballistic electron Surface-emitting phenomenon" that is a kind of the tunnel effect. ~~Since~~ Because heat generated from the strong field drift layer **12** is released through the silicon grains **100**, it is possible to avoid the occurrence of popping at the time of the electron emission.

Page 9, please delete the paragraph beginning at line 18 and substitute therefor the following:

Electrons emitted from the cold cathode electron emitter **1** [[is]] are called [[as]] "cold electrons". On the contrary, electrons generated from a spot-like or linear electron emitter such as hot filament by heating [[is]] are called [[as]] "thermal electrons". In addition, the cold cathode electron emitter 1 used in the present invention is known as [[an]] a field-emission type electron source that is preferably used for display devices, for example, as disclosed in Japanese Patent Early Publication No. 2000-100316.

Page 9, please delete the paragraph beginning at line 25 and substitute therefor the following:

The electrons provided from the cold cathode electron emitter **1** through the opening **21** of the case **20** are irradiated to a surface to be modified of the object **2** supported by the holder **40**. An energy of the electrons irradiated can be determined according to the purpose of the modifying treatment. For example, to avoid radio activation of the object, it is preferred to use [[the]] an energy level of less than 10 MeV, and, more preferably, less than 1 MeV. In the case of using [[the]] an energy level smaller than 300 keV, a radiological protection equipment for X-ray can be simplified.

Page 10, please delete the paragraph beginning at line 3 and substitute therefor the following:

To achieve desired modifying effects that meet the purpose of the present invention, it is preferred to use electrons having an energy selected from a range of 1 to 50 keV, and, more particularly, 1 to 100 eV. When irradiating the electrons having [[the]] an energy of approximately 4 eV, atoms and molecules can be excited. In addition, when irradiating [[the]] electrons having an energy of 4 to 12 eV, which is equal to or slightly larger than 4 to 8 eV of the bonding energy between atoms, the object can be effectively surface modified. When irradiating [[the]] electrons having an energy of 20 to 100 eV, atoms and molecules can be ionized. Furthermore, when irradiating [[the]] electrons having an energy smaller than the ionization energy to a gas containing moisture or steam as the object, the electrons are attached to the object, so that minus ions can be readily generated.

Page 11, please delete the paragraph beginning at line 11 and substitute therefor the following:

In FIG. 3, when an electric current flowing between the first and second electrodes (**11**, **17**) is represented as a diode current **Ips**, and an electric current flowing between the accelerating electrode **50** and the first electrode **11** is represented as an emission current **Ie**, an electron emissivity can be defined as a rate of the emission current **Ie** to the diode current **Ips** (=**Ie/Ips**). As this ratio is larger, the electron emissivity increases. According to the present invention, even when a relatively low voltage of 10 to 20 V is applied as the voltage **Vps** between the first and second electrodes (**11**, **17**), it is possible to emit [[the]] electrons. In addition, ~~since~~ because the dependence of the electron emissivity on degree of vacuum is small, and popping does not happen at the time of electron emission, it is possible to stably emit the electrons at an improved electron emissivity. This means that electrons can be emitted at a pressure in the vicinity of atmospheric pressure. As the voltage **Vps**, a constant DC voltage or a pulse voltage can be used. In the case of using the pulse voltage, a reverse-bias voltage may be applied when the voltage **Vps** is not applied. Similarly, as the acceleration voltage **Vc**, a constant DC voltage or a pulse voltage can be used.

Page 12, please delete the paragraph beginning at line 6 and substitute therefor the following:

(1) ~~Since~~ Because the cold cathode electron emitter having [[the]] a planar electron emitting portion is used, it is possible to uniformly irradiate electrons to a wide surface area of the object at a time, as compared with the case of using an electron emitting source having a spot-like or linear electron emitting portion such as hot filament. As a result, improved modification efficiency and uniformity can be achieved.

Page 12, please delete the paragraph beginning at line 12 and substitute therefor the following:

(2) The cold cathode electron emitter such as BSD has [[the]] a capability of emitting electrons under atmospheric pressure. Therefore, it is possible to perform the modifying treatment without using vacuum equipments such as decompression chamber and vacuum pump.

Page 12, please delete the paragraph beginning at line 16 and substitute therefor the following:

(3) The cold cathode electron emitter can be driven by a pulse voltage because a rise time needed to emit the electrons is shorter than the electron emitting source for emitting thermal electrons such as hot filament. Therefore, there is an advantage of ~~saving~~ reducing power consumption.

Page 12, please delete the paragraph beginning at line 20 and substitute therefor the following:

(4) ~~Since~~ Because no device for scanning the electron beam is needed in the present invention, a further reduction in cost of the apparatus can be achieved.

Page 12, please delete the paragraph beginning at line 22 and substitute therefor the following:

As a modification of this embodiment, as shown in FIG. 6, it is ~~preferred~~ preferable that a pair of cold-cathode electron emitters **1**, each of which is the cold-cathode electron emitter explained above, are disposed such that electrons are emitted in opposite [[two]] directions through a pair of openings **21** formed in the case **20**. In this case, the second electrodes **17** of the pair of cold-cathode electron emitters are respectively connected to opposite surfaces of the insulating substrate **16**, as shown in FIG. 7A Alternatively, it is ~~preferred~~ preferable that the ohmic electrodes **15** of the pair of cold-cathode electron emitters are composed of a common electrode disposed between strong field drift layers **12**, as shown in FIG. 7B. In this case, electrons are emitted in opposite [[two]] directions by applying a voltage between the common electrode **15** and the first electrodes **11** of the cold-cathode electron emitters. Therefore, it is possible to simplify the voltage applying unit by reducing the number of electrodes.

Page 13, please delete the paragraph beginning at line 5 and substitute therefor the following:

In addition, by forming a two or three dimensional array of at least one cold cathode electron emitter having the capability of simultaneously emitting the electrons in [[the]] opposite [[two]] directions, as shown in FIG. 7A or 7B, and at least one cold cathode electron emitter having the capability of emitting the electrons in one direction, as shown in FIG. 2 or 3, it is possible to design a high-efficiency modifying apparatus for simultaneously irradiating electrons to the object from different directions. For example, a modifying apparatus shown in FIG. 8 has a pair of treatment spaces, in each of which electrons can be simultaneously irradiated from the opposite two directions. In FIG. 8, the numeral **72** designates a gas supply unit for supplying a gas as the object into the case. Therefore, the gas activated by the electrons in the treatment spaces is ejected outside through the opening **21** of the case **20**.

Page 13, please delete the paragraph beginning at line 17 and substitute therefor the following:

A modifying apparatus according to a modification of this embodiment is shown in FIG. 9. This apparatus ~~is characterized by comprising~~ comprises a holder **40** for supporting the object **2**, and an emitter traveling unit **60** for traveling the case **20** with the cold cathode electron emitter **1** therein around the object. As the emitter traveling unit, for example, it is ~~preferred~~ preferable that a rail **61** is formed along a desired trajectory, and a carrier **63** for the case **20** is traveled along the rail. In this case, it is possible to selectively irradiate the electrons to a desired surface area of the object, without moving the object, and to also change the irradiation angle of the electrons to the object.

Page 13, please delete the paragraph beginning at line 26 and substitute therefor the following:

The emitter traveling unit **60** may further comprise a distance adjuster for moving the case **20** upward or downward against the carrier **63** to adjust the distance between the cold cathode electron emitter **1** and the object **2**. In addition, the holder **40** may be rotatable around the holder axis, if necessary. When it is needed to perform the modifying treatment in a desired gas atmosphere, it is ~~preferred~~ preferable that the above-described modifying apparatus is accommodated in a chamber with a gas supply unit for charging the gas into the chamber. In the present invention, ~~since~~ because the modifying treatment can be performed under atmospheric pressure, the structure of the chamber can be simplified as compared with the case of forming a decompression chamber. The emitter traveling unit **60** and the gas supply unit can be controlled by use of an operation panel provided outside of the chamber.

Page 14, please delete the paragraph beginning at line 9 and substitute therefor the following:

In this embodiment, an apparatus and method for modifying a gas as the object by irradiation of electrons are explained.

Page 14, please delete the paragraph beginning at line 11 and substitute therefor the following:

As shown in FIG. 10, the modifying apparatus of this embodiment ~~is characterized by comprising~~ comprises a case **20** having a gas inlet **22** for supplying the object gas into the case, and an opening **21** for providing a modified gas to the outside, and an acceleration electrode (anode electrode) **50** disposed in a face-to-face manner with an electron emitting portion **10** of a cold cathode electron emitter **1** in the case. The cold cathode electron emitter is the same as the emitter used in the first embodiment. Therefore, duplicate explanation is omitted. To avoid the influence of humidity on electron emitting efficiency of the cold cathode electron emitter, it is ~~preferred~~ preferable that the gas supplied in the case **20** through the gas inlet **22** is a dry gas having a low moisture content. For example, it is ~~preferred~~ preferable that the relative humidity (RH%) is smaller than 30%, and more preferably 10%. In [[the]] this case, electrons emitted from the cold cathode electron emitter **1** are accelerated toward the acceleration electrode **50**, and irradiated to the gas existing in a space between the cold cathode electron emitter and the acceleration electrode to ionize the gas. As a result, the ionized gas is provided outside through the opening **21**.

Page 14, please delete the paragraph beginning at line 27 and substitute therefor the following:

For example, negative ions can be readily generated by supplying the dry gas containing an element having positive electron affinity or a large electron affinity such as oxygen in the case **20** through the gas inlet **21**. In this case, it is ~~preferred~~ preferable to apply an acceleration voltage **Vc** of several volts to several ten volts between the acceleration electrode **50** and the first electrode **11**. The generated negative ions provided through the opening **21** are bonded with molecules in the outside air to generate various sorts of ions. On the other hand, when a voltage of several ten volts to several mega volts, which is larger than the ionization energy (for example, several ten electron volts) of the dry gas, is applied between the acceleration electrode **50** and the first electrode **11**, positive ions can be generated.

Page 15, please delete the paragraph beginning at line 8 and substitute therefor the following:

It is also ~~preferred~~ preferable that an auxiliary electrode (not shown) is placed outside of the case **20** in front of the opening **21** to control the amounts of ions ejected therefrom. In the case of ejecting the negative ions from the opening **21**, it is ~~preferred~~ preferable that an electric potential of the auxiliary electrode is determined to be higher than the electric potential of the first electrode **11** of the cold cathode electron emitter **1**. In addition, as shown in FIG. 11, a pair of auxiliary electrodes (**55**, **56**) may be disposed in the case **20** such that one of the auxiliary electrodes **55** is positioned adjacent to the cold cathode electron emitter **1** and at the side of the opening **21**, and the other auxiliary electrode **56** is positioned adjacent to the acceleration electrode **50** at the side of the opening. In this case, it is preferred that an electric potential of the auxiliary electrodes (**55**, **56**) is determined to be higher than the first electrode **11** of the cold cathode electron emitter **1** to eject the negative ions from the opening **21**.

Page 15, please delete the paragraph beginning at line 21 and substitute therefor the following:

The structure of the auxiliary electrode is not specifically limited. For example, the auxiliary electrode ~~comprises~~ may comprise a mesh electrode, grid electrode, electrode obtained by concentrically arranging ring-like electrode members having different diameters, and an electrode obtained by arranging a plurality of linear electrode members in parallel with each other. In addition, the modifying apparatus may comprise a spray unit for spraying a second gas containing liquid particles such as medical constituents or steam to the ions ejected through the opening **21** of the case **20**. In this case, the second gas can be ionized by the ions provided from the case.

Page 16, please delete the paragraph beginning at line 30 and substitute therefor the following:

In this embodiment, a modifying apparatus and method for irradiating electrons to a gas or a gas containing liquid particles such as steam or moisture are explained.

Page 17, please delete the paragraph beginning at line 3 and substitute therefor the following:

That is, as shown in FIG. 15, this modifying apparatus ~~is characterized by using~~ uses a case **20** comprising gas inlets **22** for supplying a gas into the case, which are formed in lower portions of side walls of the case, and an opening **21** for ejecting electrons emitted from the cold cathode electron emitter **1**, which is formed in a top wall at a position facing the electron emitting portion **10** of the cold cathode electron emitter placed on a bottom wall of the case. In addition, this apparatus has an accelerating electrode **50** disposed above the opening, and a gas flow channel **70** provided on the top wall of the case **20**. In this case, the gas is supplied as the object to the gas flow channel **70** from a gas supply unit **72**, as shown by the horizontal arrow in FIG. 15, and then modified by the electrons accelerated from the cold cathode electron emitter **1** toward the acceleration electrode **50** through the opening **21**. In addition, an auxiliary electrode **55** configured in a ring shape is attached to the inner surface of the top wall of the case around the opening **21**. It is ~~preferred~~ preferable that an electric potential of the auxiliary electrode **55** is determined to be higher than the electric potential of the first electrode **11** of the cold cathode electron emitter **1**, and an electric potential of the accelerating electrode **50** is determined to be higher than the electric potential of the auxiliary electrode **55**.

Page 17, please delete the paragraph beginning at line 21 and substitute therefor the following:

In this embodiment, it is ~~preferred~~ preferable that the gas supplied in the case **20** through the gas inlet **22** is a gas composed of atoms or molecules having a smaller electron affinity than oxygen. For example, such a gas comprises helium, argon, xenon, and nitrogen. In this case, the electron emitted from the cold cathode electron emitter **1** can be efficiently provided to the gas flowing in the gas flow channel **70** . In

other words, when the air is charged in the case **20**, the number of electrons having a sufficient energy for achieving the purpose of the modifying treatment may decrease, or variations in energy distribution of the electrons may increase because of interference of the electrons emitted from the cold cathode electron emitter with atoms and molecules in the air. ~~Due to this reason~~ As a result, when the air is charged in the case, it is preferred that the gas flow channel **70** is spaced from the electron emitting portion **10** of the cold cathode electron emitter **1** by a distance of 5 mm to 1 cm to perform the modifying treatment.

Page 18, please delete the paragraph beginning at line 5 and substitute therefor the following:

On the other hand, when the gas having a smaller electron affinity than oxygen is charged in the case **20**, the gas flow channel **70** can be spaced from the electron emitting portion **10** by a larger distance of several cm to several ten cm. As a result, [[it]] this leads to an improvement in modifying efficiency and a higher degree of freedom of designing the apparatus. In addition, it is possible to prevent contamination of the cold cathode electron emitter **1**, and prolong the maintenance cycle. The gas supplied into the gas flow channel **70** may contain medical constituents as the liquid particles.

Page 18, please delete the paragraph beginning at line 13 and substitute therefor the following:

As a modification of this embodiment, in the case of irradiating electrons to a liquid as the object, it is ~~preferred~~ preferable that the cold cathode electron emitter **1** is disposed on the inner surface of the top wall of the case **20**, and electrons emitted downwardly from the cold cathode electron emitter are irradiated to the liquid through the opening **21** formed in the bottom wall of the case, as shown in FIG. 16. In FIG. 16, the numeral **80** designates a liquid flow channel disposed under the case **20**. The liquid is supplied to the liquid flow channel **80** by a liquid supply unit **82**. In addition, by replacing the liquid flow channel **80** with a conveyer **90** such as a belt conveyer, as

shown in FIG. 17, it is possible to successively modify solid objects on the conveyer **90** by the irradiation of electrons.

Page 19, please delete the paragraph beginning at line 18 and substitute therefor the following:

To readily change the electron irradiation area, it is ~~preferred~~ preferable that the modifying apparatus further comprises a first selector for selecting at least one of the first electrode strips **X1** to **X8**, and a second selector for selecting at least one of the second electrode strips **Y1** to **Y8**, and a controller for controlling the voltage applying unit in response to outputs of the first and second selectors. In this case, the controller controls the voltage applying unit such that the voltage is applied between at least one of the first electrode strips **X1** to **X8** selected by the first selector and at least one of the second electrode strips **Y1** to **Y8** selected by the second selector to selectively generate the electrons from the intersecting region(s) therebetween.

Page 20, please delete the paragraph beginning at line 11 and substitute therefor the following:

In addition, it is ~~preferred~~ preferable that the ~~whole~~ entire object **2** is positioned in an electron penetrating region **Rp**, which is defined over a distance in a normal direction to the electron emitting surface of the cold cathode electron emitter **1**. The distance is determined such that the electrons emitted from the cold cathode electron emitter **1** can pass through the object **2** placed in the electron penetrating region **Rp**. For example, when the object is a liquid or solid, it is preferred that the distance is smaller than 1 mm. In addition, when the object is a gas, it is preferred that the distance is smaller than 10 cm. As described below, this method is useful to activate the inside as well as the surface of the object by the irradiation of electrons.